1        1.   A device for detecting a specific material that
2 may be present in an ensemble of objects comprising means to
3 expose an area of the ensemble to x-ray energies to produce
4 dual energy image information of the ensemble and means to
5 computer-process such dual energy information to detect said
6 specific material on the basis of comparisons of selected
7 subareas of said exposed area to other subareas in the
8 vicinity of said selected subareas.

1        2.   A device for detecting a bomb that may be
2 present in a container of objects comprising means to expose
3 an area of the container to x-ray energies to produce dual
4 energy image information of the container and its contents
5 and means to computer-process such dual energy information
6 to detect said bomb on the basis of comparisons of selected
7 subareas of said exposed area to other subareas in the
8 vicinity of said selected subareas.

1        3.   A device for detecting a specific material that
2 may be present in an ensemble of objects comprising means to
3 expose an area of the ensemble to x-rays of at least two
4 substantially different energy bands to produce dual energy
5 image information of the ensemble and means to computer-
6 process such dual energy information to detect said specific
7 material on the basis of comparisons between attenuation
8 image information from at least one of said energy bands and
9 positionally corresponding image information of parameter P
10 values derived from correlations of said dual energy image
11 information with values in a predetermined lookup table
12 reflecting attenuation at high and low energy bands over a
13 range of thicknesses of a selected specific material and a
14 range of thicknesses of a representative overlay material,
15 with attenuation of a constant thickness of said overlay

16   material and varying thicknesses of said specific material
17   represented by said parameter P.


1       4.  The device of claim 3 wherein the means to
2   computer-process includes means for evaluating gradients of
3   values in at least one of the images.


1       5.  The device of claim 4 wherein the means to
2   computer-process includes means for evaluating gradients of
3   values in both said attenuation image and said image of  P
4   values.


1       6.  The device of claim 4 having means for selecting
2   the regions of said attenuation image information for said
3   comparisons on the basis of the steepness of gradients of
4   attenuation values in said attenuation image.


1       7.  The device of claim 4, 5 or 6 wherein said means
2   for selecting employs an edge finding operator.


1       8.  The device of claim 6 including means for
2   generating gradient values $H_s$ for substantially all subareas
3   and means for pruning to remove subareas with $H_s$ values
4   below a selected threshold, and means for thereafter
5   performing said comparisons using the remaining $H_s$ values.


1       9.  A device for detecting and indicating the
2   probable presence of a specific material in an ensemble of
3   objects, comprising
4       means for exposing said item to x-rays of at least
5   two substantially different energy levels,

6        ·    means for generating for each subarea over the

7   exposed area a set of data values representing logarithms of

8   x-ray attenuation at said subarea at each of said energy

9   levels,

10        means for processing said data for said subarea to

11   compute the values of (H,L) for said subarea, wherein H is

12   the logarithm of the attenuation of said x-rays at said

13   subarea at the higher energy level and L is the logarithm of

14   the attenuation of said x-rays at said subarea at the lower

15   energy level, and

16        means for applying an edge finding or gradient

17   evaluating operator such as a Sobel operator to image data

18   of at least one energy level,

19        means for generating gradient values $H_s$ for

20   substantially all subareas,

21        means for pruning to remove subareas with gradient

22   values $H_s$ below a selected gradient threshold,

23        means for determining for remaining subareas with

24   gradient values $H_s$ above said selected gradient threshold

25   parameter P values using a lookup table in computer storage

26   reflecting x-ray attenuation at high and low energy bands

27   over a range of thicknesses of said selected specific

28   material and a range of thicknesses of a representative

29   overlay material, with attenuation of a constant thickness

30   of said overlay material and varying thicknesses of said

31   specific material represented by said parameter P,

32        means for applying said gradient evaluating operator

33   to P image data formed using said parameter P values for

34   said remaining subareas,

35        means for generating gradient values $P_s$ for said

36   remaining subareas,

37        · means for calculating a ratio $H_s/P_s$ for said
38  remaining subareas,
39        means for raising said ratio to a power at least as
40  large as unity to emphasize large values of said ratio, and
41        means for storing said ratio $H_s/P_s$ raised to said
42  power for substantially all of said remaining subareas.


1        10.  The device of claim 9 further comprising
2        means for selecting an alarm threshold on said ratio
3   $H_s/P_s$ raised to said power so that subareas having said
4   ratio $H_s/P_s$ raised to said power above said alarm threshold
5   are strongly indicative of presence of said specific
6   material,
7        means for applying a dilation algorithm using said H
8   values and said L values for said image data,
9        means for sounding an alarm if a certain number of
10  subarea values are above said alarm threshold,
11        means for applying an erosion algorithm to eliminate
12  spurious noise in said image data, and
13        means for displaying said image data with areas of
14  particular interest highlighted.


1        11.  A device for detecting and indicating the
2   probable presence of a specific material in an ensemble of
3   objects, comprising
4        means for exposing said item to x-rays of at least
5   two substantially different energy levels,
6        means for generating for each subarea over the
7   exposed area a set of data values representing logarithms of
8   x-ray attenuation at said subarea at each of said energy
9   levels,
10        means for filtering said data for said subarea,

11    means for averaging said data for said subarea,

12    means for processing said data for said subarea to

13 compute the values of (H,L) for said test subarea, wherein H

14 is the logarithm of the attenuation of said x-rays at said

15 subarea at the higher energy level and L is the logarithm of

16 the attenuation of said x-rays at said subarea at the lower

17 energy level, and

18    means for applying an edge finding or gradient

19 evaluating operator such as a Sobel operator to image data

20 of at least one energy level,

21    means for generating gradient values $H_s$ for

22 substantially all subareas,

23    means for pruning to remove subareas with gradient

24 values $H_s$ below a selected gradient threshold,

25    means for determining for remaining subareas with

26 gradient values $H_s$ above said selected gradient threshold

27 parameter P values using a lookup table in computer storage

28 reflecting x-ray attenuation at high and low energy bands

29 over a range of thicknesses of said selected specific

30 material and a range of thicknesses of a representative

31 overlay material, with attenuation of a constant thickness

32 of said overlay material and varying thicknesses of said

33 specific material represented by said parameter P,

34    means for applying said gradient evaluating operator

35 to P image data formed using said parameter P values for

36 said remaining subareas,

37    means for generating gradient values $P_s$ for said

38 remaining subareas,

39    means for calculating a ratio $H_s/P_s$ for said

40 remaining subareas,

41    means for raising said ratio to a power at least as

42 large as unity to emphasize large values of said ratio,

43      · means for storing said ratio $H_s/P_s$ raised to said

44  power for substantially all of said remaining subareas,

45      means for selecting an alarm threshold on said ratio

46  $H_s/P_s$ raised to said power so that subareas having said

47  ratio $H_s/P_s$ raised to said power above said alarm threshold

48  are strongly indicative of presence of said specific

49  material,

50      means for applying a dilation algorithm using said H

51  values and said L values for said image data,

52      means for sounding an alarm if a certain number of

53  subarea values are above said alarm threshold,

54      means for applying an erosion algorithm to eliminate

55  spurious noise in said image data, and

56      means for displaying said image data with areas of

57  particular interest highlighted.


1      12. A device for inspecting an ensemble of physical

2  objects comprising means to expose an area of said ensemble

3  to x-rays of at least two substantially different energy

4  bands, detection means responsive to said x-rays passing

5  through said ensemble to generate for subareas over said

6  area respective sets of values representing the attenuation

7  of said x-rays at each of said energy bands, comparison

8  means operative on differences in attenuation between

9  subareas in a neighborhood to determine the presence of a

10  specific material in the neighborhood, and indicating means

11  responsive to said comparisons for indicating presence of

12  said specific material in said ensemble.


1      13. The device of claim 12 wherein said comparison

2  means includes a lookup table reflecting attenuation at high

3  and low energy bands over a range of thicknesses of a

4   selected specific material and a range of thicknesses of a
5   representative overlay material, with attenuation of a
6   constant thickness of said overlay material and varying
7   thicknesses of said specific material represented by a
8   parameter P.

1          14.   The device of claim 13 including means to
2   reference actual attenuation measurements of subareas at an
3   energy band with parameter P values for said subareas, and
4   using said determination in determining the presence of said
5   specific material.

1          15.   The device of claim 12 wherein said comparison
2   means include means to combine, according to a predetermined
3   formula, values representing the attenuation of said x-rays
4   for subareas in said neighborhood to provide an attenuation
5   measure and means to compare said measure to a reference
6   related to said specific material.

1          16.   The device of claim 12 wherein said values
2   generated representing the attenuation of said x-rays at
3   said energy bands are logarithms of x-ray attenuation at
4   each of said energy bands at each subarea.

1          17.   The device of claim 12 wherein said comparison
2   means comprises means for computing for a selected test
3   subarea of said area the values $(H_T, L_T)$ wherein $H_T$ is the
4   logarithm of the attenuation of said x-rays at said higher
5   energy band at said test subarea and $L_T$ is the logarithm of
6   the attenuation of said x-rays at said lower energy band at
7   said test subarea, means for computing for a subarea nearby
8   said test subarea the values $(H_B, L_B)$ wherein $H_B$ is the

9   logarithm of the attenuation of said x-rays at said higher

10  energy band at said nearby subarea and $L_B$ is the logarithm

11  of the attenuation of said x-rays at said lower energy band

12  at said nearby subarea, said comparison means constructed to

13  employ said values $(H_T, L_T)$ and $(H_B, L_B)$ in determining the

14  presence of said specific material.


1       18.  The device of claim 17 further comprising means

2  for providing p-values P representing attenuation

3  characteristics of various overlying materials, means for

4  associating a p-value $P_T$ with said values $(H_T, L_T)$ wherein

5  said p-value $P_T$ is proportional to the thickness of

6  overlying materials at said test subarea, means for

7  associating a p-value $P_B$ with said values $(H_B, L_B)$ wherein

8  said p-value $P_B$ is proportional to the thickness of

9  overlying materials at said nearby subarea, means for

10  computing the value of $|(H_T-H_B)/(P_T-P_B)| = \Delta H/\Delta P$ and means

11  for associating $\Delta H/\Delta P$ with a relative probability measure

12  for the presence of said specific material at respective

13  subareas.


1       19.  The device of claim 18 wherein the relative

2  probability measure is proportional to $(\Delta H/\Delta P)^q$, wherein q

3  is a value chosen to emphasize extrema of the value of

4  $\Delta H/\Delta P$.


1       20.  The device of claim 19 wherein q=2.


1       21.  The device of claim 18 wherein said means for

2  associating a p-value P with said values (H,L) involves

3  identifying said values with respective points from a set of

4  points previously generated by numerically varying

5 thicknesses of said specific material and said overlying
6 materials.

1       22. The device of claim 17 wherein said comparison
2 means comprises means for computing the value of
3 $(H_T-H_B)/(L_T-L_B) = K_{TB}$ and means for comparing said value of
4 $K_{TB}$ with the value of $K_{MAT}$ wherein $K_{MAT}$ is an attenuation
5 characteristic of said specific material.

1       23. The device of claim 22 wherein $K_{MAT}$ is a stored
2 value developed by prior measurements.

1       24. The device of claim 22 wherein
2 $K_{MAT} = \mu_H/\mu_L$ wherein $\mu_H$ is the attenuation coefficient of
3 said specific material exposed to said higher energy band
4 x-rays and $\mu_L$ is the attenuation coefficient of said
5 specific material exposed to said lower energy band x-rays.

1       25. The device of claim 12 further comprising means
2 for exposing selected numbers of samples of various known
3 materials each of a range of different thicknesses to said
4 x-rays of said different energy bands to measure the
5 attenuation characteristic of the exposed samples to provide
6 a reference for said comparison means.

1       26. The device of claim 25 including calculation
2 means for interpolating between said measured values to
3 estimate intermediate values for use in making said
4 comparison.

1       27. The device as in any of claims 3-26 further
2 comprising means for assigning to subareas over said exposed

3  area of the object relative probabilities for the presence
4  of said specific material based upon said comparisons, said
5  indicating means being responsive to said relative
6  probability assignments for indicating presence of said
7  specific material in said object.

1      28.  A baggage inspection device for detecting and
2  indicating the probable presence of a specific material in
3  an item of baggage comprising means to expose an area of
4  said item to x-rays of at least two substantially different
5  energy bands, detection means responsive to said x-rays
6  passing through said item to generate for subareas over said
7  area respective sets of values representing the attenuation
8  of said x-rays at each of said energy bands, comparison
9  means operative on differences in attenuation between
10  subareas in a neighborhood to determine the presence of a
11  specific material in the neighborhood of said subareas, and
12  indicating means responsive to said comparisons for
13  indicating presence of said specific material in said item,
14  said comparison means comprising means for computing for a
15  selected test subarea of said area the values $(H_T, L_T)$
16  wherein $H_T$ is the logarithm of the attenuation of said
17  x-rays at said higher energy band at said test subarea and
18  $L_T$ is the logarithm of the attenuation of said x-rays at
19  said lower energy band at said test subarea, means for
20  computing for a subarea nearby said test subarea the values
21  $(H_B, L_B)$ wherein $H_B$ is the logarithm of the attenuation of
22  said x-rays at said higher energy band at said nearby
23  subarea and $L_B$ is the logarithm of the attenuation of said
24  x-rays at said lower energy band at said nearby subarea,
25  said comparison means constructed to employ said values

26  $(H_T, L_T)$ and $(H_B, L_B)$ in determining the presence of said

27  specific material.


1  29.  The device of claim 28 wherein said comparison

2  means comprises

3  means for providing p-values $P$ representing

4  attenuation characteristics of various overlying materials,

5  means for associating a p-value $P_T$ with said values

6  $(H_T, L_T)$ wherein said p-value $P_T$ is proportional to the

7  thickness of overlying materials at said test subarea, means

8  for associating a p-value $P_B$ with said values $(H_B, L_B)$

9  wherein said p-value $P_B$ is proportional to the thickness of

10  overlying materials at said nearby subarea, means for

11  computing the value of $|(H_T - H_B)/(P_T - P_B)| = \Delta H/\Delta P$ and means

12  for associating $\Delta H/\Delta P$ with a relative probability measure

13  for the presence of said specific material at respective

14  subareas.


1  30.  The device of claim 13, 14, 18 or 29, including

2  means for examining said subareas,

3  means responsive thereto for producing values for

4  each subarea indicative of the relative probability of

5  matching said specific material,

6  means for displaying subareas over said area, and

7  means for highlighting those subareas having a

8  probability greater than or equal to a selected threshold

9  value of matching said specific material.


1  31.  The device of claim 28 wherein said comparison

2  means comprises means for computing the value of

3  $(H_T - H_B)/(L_T - L_B) = K_{TB}$ and means for comparing said value of

4    $K_{TB}$ with the value of $K_{MAT}$ wherein $K_{MAT}$ is an attenuation

5    characteristic of said specific material.

 

1        32.  The device of claim 17 or 28, wherein $K_{MAT}$ =

2    $\mu_H(H_T, L_T, H_B, L_B)/\mu_L(H_T, L_T, H_B, L_B)$ wherein $\mu_H$ is an attenuation

3    coefficient of said specific material exposed to said higher

4    energy x-rays, comprising a function of the logarithms of

5    the attenuation of said x-rays at said test subarea and at

6    said nearby subarea, wherein $\mu_L$ is an attenuation

7    coefficient of said specific material exposed to said lower

8    energy x-rays, comprising a function of said logarithms of

9    the attentuation of said x-rays at said test subarea and at

10    said nearby subarea.

 

1        33. The device of claim 32 including

2        means for ascertaining whether said value of $K_{TB}$ is

3    within a selected window of values of $K_{MAT}$,

4        means for incrementing a respective counter if said

5    value of $K_{TB}$ is within said window,

6        means for examining said subarea counters and

7    producing values for each subarea indicative of the relative

8    probability of matching said specific material,

9        means for displaying subareas over said area, and

10        means for highlighting those subareas having a

11    probability greater than or equal to a selected threshold

12    value of matching said specific material.

 

1        34. The device of claim 1, 2, 3 or 12 wherein said

2    means to expose said area further comprises an x-ray source,

3    means for generating from said source x-rays of at least two

4    substantially different energy bands, means for collimating

5 a fan beam of said x-rays, and means for conveying said
6 object to intercept said fan beam of said x-rays.

1        35. The device of claim 12, wherein said indicating
2 means is a visual display of an x-ray image, and said
3 indication being of the form of distinguished subareas at
4 which the specific material is probably present.

1        36. The device of claim 1, 2, 3, 12 or 28, wherein
2 said specific material is a threatening substance.

1        37. The device of claim 36, wherein said threatening
2 substance is an explosive.

1        38. The device of claim 1, 2, 3, 12 or 28, wherein
2 said specific material is an illicit drug substance.

1        39. The device of claim 1, 3 or 12, wherein said
2 ensemble comprises components of a stream of matter.

1        40. The device of claim 39, wherein said stream is
2 comprised of rocks and other materials, and said specific
3 material is a mineral of value.

1        41. The device of claim 39, wherein said stream is
2 shredded plastic refuse, and said specific material is a
3 particular form of plastic.

1        42. The device of claim 41, wherein said particular
2 form of plastic comprises halogenated hydrocarbon plastic to
3 be separated from other plastic refuse.

1      43. The device of claim 1, 3 or 12, wherein said
2  ensemble comprises foodstuffs.

1      44. The device of claim 43, wherein said foodstuffs
2  are meat, and wherein said specific material is bone.

1      45. The device of claim 43, wherein said specific
2  material is inorganic.

1      46. The device of claim 1 or 2 further comprising
2  means for locating edges in the exposed area where one
3  material overlaps another, means for choosing subareas in
4  close proximity to said edges to be said selected subareas,
5  and means for assigning to said selected subareas a relative
6  probability for the presence of said specific materials at
7  said subareas based upon said comparisons with other
8  subareas in the vicinity, and indicating means responsive to
9  said relative probability assignment.

1      47. The device of claim 12 further comprising means
2  for locating edges in the exposed area where one material
3  overlaps another, means for choosing subareas in close
4  proximity to said edges to be said selected subareas, and
5  means for assigning to said selected subareas a relative
6  probability for the presence of said specific materials at
7  said subareas based upon comparisons with other subareas in
8  the neighborhood, said indicating means being responsive to
9  said relative probability assignment.

1      48. The device of claim 1, 2, 12, 46 or 47 further
2  comprising means for dilating indications of subareas over
3  regions whose edges have been determined to indicate the
4  presence of said specific material, wherein said dilation

5     makes said regions more prominently noticeable to an

6     operator of said device, and wherein said dilation enhances

7     indication of presence of said specific material.


1        49.   A method of detecting a specific material that

2     may be present in an ensemble of objects comprising exposing

3     an area of the ensemble to x-ray energies to produce dual

4     energy image information of the exposed ensemble and

5     computer-processing such dual energy information to detect

6     said specific material on the basis of comparisons of

7     selected subareas of said exposed area to other subareas in

8     the vicinity of said selected subareas.


1        50.   A method of detecting a bomb that may be

2     present in a container of objects comprising exposing an

3     area of the container to x-ray energies to produce dual

4     energy image information of the exposed container and

5     computer-processing such dual energy information to detect

6     said bomb on the basis of comparisons of selected subareas

7     of said exposed area to other subareas in the vicinity of

8     said selected subareas.


1        51. A method of baggage inspection for detecting and

2     indicating the probable presence of a specific material in

3     an item of baggage, comprising the steps of

4        exposing said item to x-rays of at least two

5     substantially different energy levels,

6        generating for each subarea over the exposed area a

7     set of data values representing logarithms of x-ray

8     attenuation at said subarea at each of said energy levels,

9        choosing a test subarea,

10       filtering said data for said test subarea,

11       averaging said data for said test subarea,

12         processing said data for said test subarea to

13 compute the values of $(H_T, L_T)$ for said test subarea, wherein

14 $H_T$ is the logarithm of the attenuation of said x-rays at

15 said test subarea at the higher energy level and $L_T$ is the

16 logarithm of the attenuation of said x-rays at said test

17 subarea at the lower energy level, and

18         choosing a background subarea,

19         filtering said data for said background subarea,

20         averaging said data for said background subarea,

21         processing said data for said background subarea to

22 compute the values of $(H_B, L_B)$ for said background subarea,

23 wherein $H_B$ is the logarithm of the attenuation of said

24 x-rays at said background subarea at the higher energy level

25 and $L_B$ is the logarithm of the attenuation of said x-rays at

26 said background subarea at the lower energy level, and

27         computing the value of $K_{TB}$ = $(H_T - H_B)/(L_T - L_B)$, and

28         comparing said value of $K_{TB}$ to the value of $K_{MAT}$,

29 wherein $K_{MAT} = \mu_H(H_T, L_T, H_B, L_B)/\mu_L(H_T, L_T, H_B, L_B)$ wherein $\mu_H$, an

30 attenuation coefficient of a specific material exposed to

31 said higher energy x-rays, is a function of the logarithms

32 of the attenuation of said x-rays at said test subarea and

33 at said background subarea, wherein $\mu_L$, an attenuation

34 coefficient of said specific material exposed to said lower

35 energy x-rays, is a function of the logarithms of the

36 attenuation of said x-rays at said test subarea and at said

37 background subarea, and

38         ascertaining whether said value of $K_{TB}$ is within a

39 selected window of values of $K_{MAT}$, incrementing a respective

40 counter if said value of $K_{TB}$ is within said window,

41         choosing another background subarea, and

42         iterating the steps from filtering said data for

43 said background subarea to choosing another background

44 subarea until a substantial number of background subareas
45 have been so examined, and
46       choosing another test subarea, and
47       iterating the steps from filtering said data for
48 said test subarea to choosing another test subarea until
49 substantially all subareas have been so tested, and
50       examining said subarea counters,
51       producing values for each subarea indicative of the
52 relative probability of matching said specific material, and
53       displaying subareas over said area, and
54       highlighting those subareas having a probability
55 greater than or equal to a selected threshold value of
56 matching said specific material.


1       52. A method of baggage inspection for detecting
2 and indicating the probable presence of a specific material
3 in an item of baggage, comprising the steps of
4       exposing said item to x-rays of at least two
5 substantially different energy levels,
6       generating for each subarea over the exposed area a
7 set of data values representing logarithms of x-ray
8 attenuation at said subarea at each of said energy levels,
9       choosing a test subarea,
10       filtering said data for said test subarea,
11       averaging said data for said test subarea,
12       processing said data for said test subarea to
13 compute the values of $(H_T, L_T)$ for said test subarea, wherein
14 $H_T$ is the logarithm of the attenuation of said x-rays at
15 said test subarea at the higher energy level and $L_T$ is the
16 logarithm of the attenuation of said x-rays at said test
17 subarea at the lower energy level, and
18       choosing a background subarea,

19    filtering said data for said background subarea,

20    averaging said data for said background subarea,

21    processing said data for said background subarea to

22  compute the values of $(H_B, L_B)$ for said background subarea,

23  wherein $H_B$ is the logarithm of the attenuation of said x-

24  rays at said background subarea at the higher energy level

25  and $L_B$ is the logarithm of the attenuation of said x-rays at

26  said background subarea at the lower energy level, and

27    providing p-values P representing attenuation

28  characteristics of various overlying materials,

29    associating a p-value $P_T$ with said values $(H_T, L_T)$

30  wherein said p-value $P_T$ is proportional to the thickness of

31  overlying materials at said test subarea,

32    associating a p-value $P_B$ with said values $(H_B, L_B)$

33  wherein said p-value $P_B$ is proportional to the thickness of

34  overlying materials at said nearby subarea,

35    computing the value of $|(H_T-H_B)/(P_T-P_B)| = \Delta H/\Delta P$,

36    associating $\Delta H/\Delta P$ with a relative probability

37  measure for the presence of said specific material at

38  respective subareas,

39    storing said probability measure,

40    choosing another background subarea, and

41    iterating the steps from filtering said data for

42  said background subarea to choosing another background

43  subarea until a substantial number of background subareas

44  have been so examined, and

45    choosing another test subarea, and

46    iterating the steps from filtering said data for

47  said test subarea to choosing another test subarea until

48  substantially all subareas have been so tested, and

49    examining said subarea probability measure stores,

50       producing values for each subarea indicative of the

51  relative probability of matching said specific material, and

52       displaying subareas over said area, and

53       highlighting those subareas having a probability

54  greater than or equal to a selected threshold value of

55  matching said specific material.


1       53.  A method of detecting a specific material that

2  may be present in an ensemble of objects comprising the

3  steps of

4       exposing an area of the ensemble to x-rays of at

5  least two substantially different energy bands to produce

6  dual energy image information of the ensemble, and

7       computer-processing such dual energy information to

8  detect said specific material on the basis of comparisons

9  between attenuation image information from at least one of

10  said energy bands and positionally corresponding image

11  information of parameter P values derived from correlations

12  of said dual energy image information with values in a

13  predetermined lookup table reflecting attenuation at high

14  and low energy bands over a range of thicknesses of a

15  selected specific material and a range of thicknesses of a

16  representative overlay material, with attenuation of a

17  constant thickness of said overlay material and varying

18  thicknesses of said specific material represented by said

19  parameter P.


1       54.  A method of detecting and indicating the

2  probable presence of a specific material in an ensemble of

3  objects, comprising the steps of

4       exposing said item to x-rays of at least two

5  substantially different energy levels,

6       generating for each subarea over the exposed area a

7  set of data values representing logarithms of x-ray

8  attenuation at said subarea at each of said energy levels,

9       filtering said data for said subarea,

10      averaging said data for said subarea,

11      processing said data for said subarea to compute the

12 values of (H,L) for said test subarea, wherein H is the

13 logarithm of the attenuation of said x-rays at said subarea

14 at the higher energy level and L is the logarithm of the

15 attenuation of said x-rays at said subarea at the lower

16 energy level, and

17      applying an edge finding or gradient evaluating

18 operator such as a Sobel operator to image data of at least

19 one energy level,

20      generating gradient values $H_s$ for substantially all

21 subareas,

22      pruning to remove subareas with gradient values $H_s$

23 below a selected gradient threshold,

24      determining for remaining subareas with gradient

25 values $H_s$ above said selected gradient threshold parameter P

26 values using a lookup table in computer storage reflecting

27 x-ray attenuation at high and low energy bands over a range

28 of thicknesses of said selected specific material and a

29 range of thicknesses of a representative overlay material,

30 with attenuation of a constant thickness of said overlay

31 material and varying thicknesses of said specific material

32 represented by said parameter P,

33      applying said gradient evaluating operator to P

34 image data formed using said parameter P values for said

35 remaining subareas,

36      generating gradient values $P_s$ for said remaining

37 subareas,

38    calculating a ratio $H_s/P_s$ for said remaining

39 subareas,

40    raising said ratio to a power at least as large as

41 unity to emphasize large values of said ratio,

42    storing said ratio $H_s/P_s$ raised to said power for

43 substantially all of said remaining subareas,

44    selecting an alarm threshold on said ratio $H_s/P_s$

45 raised to said power so that subareas having said ratio

46 $H_s/P_s$ raised to said power above said alarm threshold are

47 strongly indicative of presence of said specific material,

48    applying a dilation algorithm using said H values

49 and said L values for said image data,

50    sounding an alarm if a certain number of subarea

51 values are above said alarm threshold,

52    applying an erosion algorithm to eliminate spurious

53 noise in said image data, and

54    displaying said image data with areas of particular

55 interest highlighted.


1    55.  The method as in any of claims 49-54 further

2 comprising employing computed tomographic information to

3 detect said specific material that may be present in

4 subareas indicated by said computer-processed dual energy

5 information as being probable subareas for the presence of

6 said specific materials.


1    56.  For use in detecting a specific material that

2 may be present in an area being exposed to x-ray energies, a

3 lookup table in computer storage reflecting x-ray

4 attenuation at high and low energy bands over a range of

5 thicknesses of said selected specific material and a range

6 of thicknesses of a representative overlay material, with

7    attenuation of a constant thickness of said overlay material

8    and varying thicknesses of said specific material

9    represented by a parameter $P$.